Wireless RF Digital System for Mouth-Embedded Multi-Sensor Communication

Ibrahim M. Abdel-Motaleb[1], Justin Lavrencik [1]

[1]Department of Electrical Engineering, Northern Illinois University, DeKalb, IL, USA

Abstract

There is urgent need to monitor dental and oral diseases, such as tooth decay, gum diseases, and teeth grinding. Such monitoring can be achieved by embedding sensors in the mouth. This technique faces some difficulties. The first is how the power needed for the operation of the sensors and the associated electronic chips can be generated. This power can be generated using the pressure exerted by the teeth during chewing on a piezoelectric device. The second is where the chip (LTC3108 power management IC) will be placed in the mouth and connected to the sensors without injuring the patient or causing discomfort. This can be solved by using a Hawley retainer [1], shown in Figure 1, since the chip is very small. The third is how the stored data can be retrieved. The paper addresses this issue and lays the framework for a design to provide digital wireless transmission of data for multiple sensors. Models of EM antenna radiation patterns are used along with circuit designs for analog to digital conversion and digital transmission. The size of the antenna is small enough to fit behind the upper row of the teeth. Our COMSOL design shows that data can be transmitted from the mouth without severe attenuation of the signal from the tissue. COMSOL is used to investigate the design of dipole antennas with impedance boundaries designed to represent different types of skin. The wireless transmission of the circuit is designed for a frequency of 5.8 GHz to accommodate a small size antenna that can fit inside the mouth. Skin depth penetrations of high-frequency EM waves are investigated with different types of biological tissues to determine if transmission through lip tissue is possible. The study shows that EM waves at the frequency of 5.8 GHz will penetrate the skin tissue around the lips. Different thicknesses of skin and fatty tissue were tested for EM wave attenuation at ranges from 2600 to 3100 um and 1 to 1.1 cm, respectively. Figure 2, Figure 3, and Figure 4 show that attenuation varies depending on the angle of incidence between the electromagnetic wave and the tissue. These attenuations vary from -3.1 to -7.3 dB normalized at 2600 um of skin to -3.9 to -8.5 dB at 3100 um skin. This range of attenuation was from an incidence angle of zero to 48.7o. The study proves that EM waves at 5.8 GHz can attenuate thin layers of tissue with a strong enough signal to transmit data. Furthermore, the study identifies the optimal angle range for receiving transmission. While this study was intended for determining if a signal can be transmitted through lips, the model can be modified to study penetration depths of signals for other areas on a human body, different biological tissue, or implanted devices.

Reference

1. "What Is a Hawley Retainer?" How Much Do Braces Cost. Web. 16 Mar. 2012. .

Figures used in the abstract

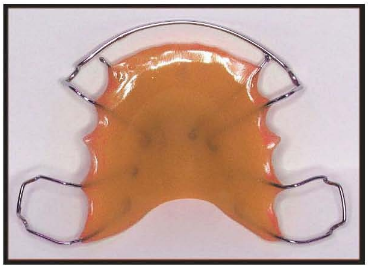

Figure 1: Picture of a Hawley retainer. The apparatus goes into the top of the mouth and fits snugly behind the teeth. It is approximately 4cmx6cm. All integrated circuit devices would be able to fit on the apparatus and have access to sensors along the top teeth [1].

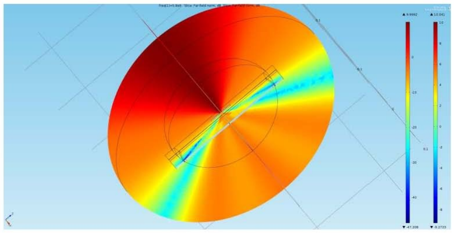

Figure 2: Skin thickness of 2600 um and fat tissue of 1 cm stretched across the antenna. Attenuation ranges from -3.1 to -7.3 dB.

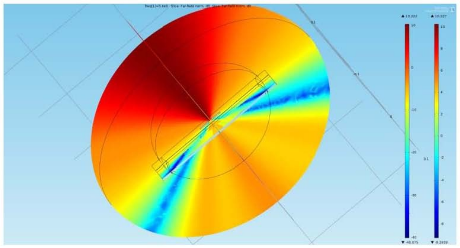

Figure 3: Skin thickness of 2900 um and fat tissue of 1.1 cm stretched across the antenna. Attenuation ranges from -3.4 to -8 dB.

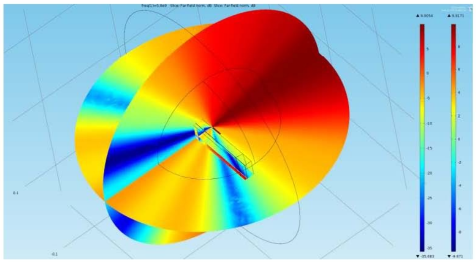

Figure 4: Skin thickness of 3100 um and fat tissue of 1.1 cm stretched across the antenna. Attenuation ranges from -3.9 to -8.5 norm dB.